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GROUND SKIDDING SECOND-GROWTH
TIMBER IN COASTAL
BRITISH COLUMBIA: A CASE STUDY

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Abstract

In 1988, two Caterpillar 518 rubber-tired cable skidders and a Caterpillar D4H Custom skidder were monitored over a four-month period while working in a Coastal British Columbia second-growth stand. Productivity, costs, and profitability were determined. Shift-level analysis showed skidding costs of \$2.46 and \$2.93/m³ for the two rubber-tired skidders and \$4.02/m³ for the D4H Custom skidder. Analysis of detailed timing data showed that skidding distance had the greatest influence on skidding cycle time. Marginal economic analysis showed that all Douglas-fir and balsam J-grade logs were skidded at a profit, while X-grade and lower-grade Douglas-fir logs and Y-grade balsam logs were skidded at a loss. Turn volume and market value had the greatest impacts on skidding profit.

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Disclaimer

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Summary

In 1988, Forestry Canada (Pacific Forestry Centre), under the Canada/British Columbia Forest Resource Development Agreement (FRDA), contracted the Forest Engineering Research Institute of Canada (FERIC) to examine the productivity and profitability of ground skidding second-growth timber in Coastal British Columbia. The study was located approximately 6 km south of Metchosin, B.C. in an area with a primarily second-growth Douglas-fir and balsam stand composition. Two Caterpillar 518 rubber-tired cable skidders and a Caterpillar D4H skidder were monitored on a shift-level basis over a four-month period. One of the Caterpillar 518 skidders was monitored at a detailed timing level for 10 days. During three of the detailed timing days, individual stems in each turn were scaled and graded. Skidding costs and profits for the detailed timing

production were estimated using marginal economic analysis techniques.

The two Caterpillar 518 skidders averaged 192 and 161 m³/8-h shift and had skidding costs of \$2.46 and \$2.93/m³ respectively. The Caterpillar D4H Custom skidder averaged 117 m³/8-h shift and showed skidding costs of \$4.02/m³.

Marginal turn size for Douglas-fir and balsam J-, X-, and Y-grade logs were determined. All X-grade Douglas-fir and all species of Y-grade logs were skidded at a loss. All J-grade logs were profitable to skid. Turn volume and market value had the greatest influence on skidding profitability.

Sampling by the line-intersect method showed that an average of 17.3 m³/ha of residue remained after harvesting.

INTRODUCTION

While an increasing proportion of the timber harvested on the Coast of British Columbia is derived from second-growth stands, experience to date has shown that the log values from these stands are lower than for timber harvested from old-growth stands. As a result, logging costs must be reduced in order for logging operations to remain profitable.

Ground conditions on many sites permit the woods manager to choose either a cable-yarding or ground-skidding system. In order to assess the profitability of harvesting Coastal second-growth stands and to choose the most efficient system, production data for ground skidding are required. A study at Rocky Point on southern Vancouver Island was initiated to provide some comparative data. The major objectives of the study were to:

- Evaluate the productivity of a rubber-tired cable skidder when skidding Coastal second-growth timber.
- Determine the profitability of a rubber-tired cable-skidder operation working in Coastal second-growth stands.
- Measure the effect of turn size and skidding distance on skidding productivity and costs.
- Undertake a marginal log analysis to determine the marginal log volume.
- Determine the volume and quality of residue on the logged blocks after skidding.

The Forest Engineering Research Institute of Canada (FERIC) was contracted by Forestry Canada (Pacific Forestry Centre) to carry out the study under the Canada/British Columbia Forest Resource Development Agreement. The study area was harvested under contract to Forestry Canada between September and December 1988. Because of a prolonged shutdown resulting from wet landing and poor haul-road conditions, the study lasted nearly four months.

STUDY APPROACH AND PROCEDURES

In order to assess skidder productivity, both shift-level and detailed-timing methods were used.

For the shift-level analysis, Model DSR Servis Recorders were mounted on the skidding machines and a chart was produced for each shift worked. Each delay over 10 min duration was identified by the operator and an explanation of its cause provided. The machine operators tallied daily piece counts, and log volumes were derived from the scale records. Shift-level data were gathered for three skidding machines over 63 machine shifts.

Detailed timing was carried out for ten days. During this period, cycle elements for one skidder were

timed using stop watches, and piece counts and skidding distances were recorded. For three days during this period, each skidded stem was scaled and graded by a licensed scaler according to B.C. Ministry of Forests standards.

For both shift-level and detailed timing periods, delay times were classified either as minor delays under 10 min duration or as non-productive delay time over 10 min duration. Minor delays were included as a portion of productive time. Non-productive delay time was further classified as either mechanical or non-mechanical delay time.

The skidding costs were derived from estimated hourly operating costs for the skidders. These costs were estimated by FERIC based on Industrial Woodworkers of America wage rates¹ plus owning and operating costs derived in consultation with the equipment supplier (Caterpillar 1988) and local contractors. The costs presented are not the actual costs incurred by the contractor, and do not include interest, overhead, supervision, or crew or equipment transportation.

Logging residue was tallied using the line-intersect method (Bailey 1970) for pieces with a minimum 10-cm top diameter. Length, butt, and top dimensions of 25% of the tallied pieces were measured to calculate the average piece size.

SITE AND SYSTEM DESCRIPTION

The study site was located at Rocky Point on the south coast of Vancouver Island, approximately 6 km south of Metchosin, B.C. A site description is presented in Table 1. Soil information was gathered during the pre-harvest assessment. Old-growth stumps from previous and current logging were present throughout the study area.

The timber was handfelled and the trees left unbucked in order to maximize tree-length skidding, although it was necessary to buck some of the larger old-growth trees in the woods to improve skidding. The majority of trees were directionally felled to facilitate butt-first skidding. Each turn was skidded to one of four landings for limbing, bucking, and loading. The stand profile and felled timber are shown in Figure 1.

Skidding was carried out on a single-shift basis by two Caterpillar 518 rubber-tired cable skidders and a Caterpillar D4H track-type skidder (Figures 2 and 3). The primary skidder was the 1987 Caterpillar 518 skidder, while the 1981 Caterpillar 518 skidder and

¹ Source: Forest Industrial Relations Ltd., Vancouver; 1988.

Table 1. Site Description

Characteristic	Description
Total area of setting	30.0 ha
Study area	19.0 ha
Range of slope	0-35%
Average slope	12%
Terrain	Even to rolling
Exposed rock	50%
Soil moisture	Moist
Soil type	
Silt	26%
Loam	40%
Sand	13%
Gravel	14%
Soil depth	≥0.3 m
Underbrush	Light to medium
Obstacles	Old-growth stumps
Net volume/ha, as produced	577 m ³ /ha
Average skidded stem size	1.36 m ³ ^a

^a From shift-level production.

the Caterpillar D4H were used as secondary machines. Machine specifications are presented in Appendices I and II.

All operators hooked and unhooked their own turns, although the landing buckler frequently assisted with unhooking the turns. The 1987 Caterpillar 518 and the Caterpillar D4H had one operator each, but several individuals operated the 1981 Caterpillar 518. All operators were experienced, except for one who operated the 1981 Caterpillar 518 for only a few days. One operator worked for all of the ten days of detailed timing on the 1987 Caterpillar 518.

A landing buckler was used throughout the study period because of the tree-length skidding practice. Loading was done with a 1979 Caterpillar 966C wheeled loader.

Highway trucks hauled pulp logs and small sawlogs to the dryland sort yard at Ladysmith, and large sawlogs to the dryland sort yard at Sooke, B.C. Pulp logs and small sawlogs comprised approximately 70% of the total volume. All logs delivered to the Sooke sort yard were individually scaled, while a one-in-eight load-sampling system was used at the Ladysmith sort yard and the remaining volume was calculated using the piece average established from the sample loads.

RESULTS AND DISCUSSION

Setting Characteristics

The study area was comprised of part of Block A and all of Block B (Figures 4 and 5). The boundary of Block A was located along timber-type boundaries, however, the boundary of Block B followed the existing road along its western perimeter, and rocky knolls



Figure 1. Stand profile and felled timber at Rocky Point study site.



Figure 2. 1987 Caterpillar 518 skidder.



Figure 3. Caterpillar D4H Custom skidder.

and patches of mature timber along its eastern boundary.

The landing locations determined the skidding distances because no logs were decked at the roadside. Skidding distances ranged from 20 m to 440 m, and averaged 160 m. Landing location permitted mainly level or favourable skids. The average skidding slope was approximately 12% favourable grade, with some short adverse skids of up to 7%. The sideslope ranged from 0-35%.

Landing construction was delayed when an equipment

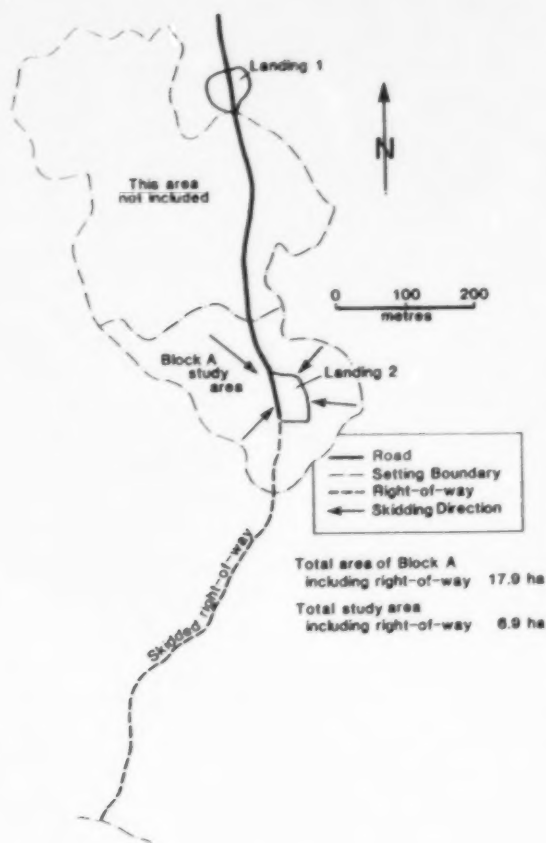


Figure 4. Block A setting layout.

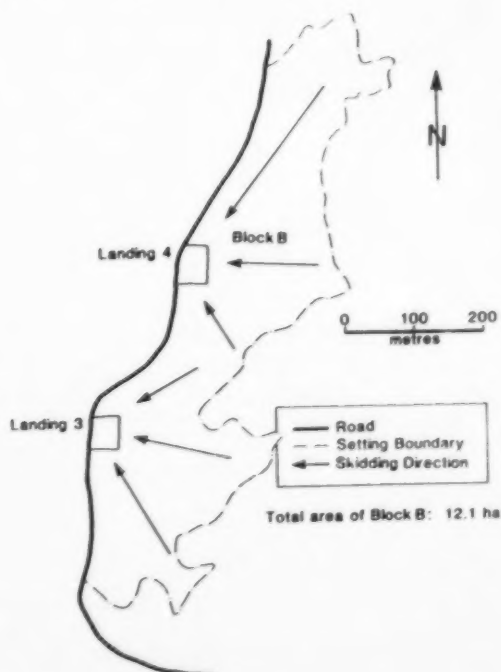


Figure 5. Block B setting layout.

operator was absent, therefore, some items were skidded to a more distant landing. The use of only two landings in Block B, and its irregularly shaped eastern boundary also contributed to the increased average skidding distance.

Skid trails were seldom constructed within the blocks; lower travel speeds were recorded for the skidders because they were obstructed by large old stumps and high stumps from the current operations. The small landing size and the poor surface condition further decreased the skidding productivity in Block B. Figures 6 and 7 show the wet conditions encountered on the landing and skid trails.

Skidding and hauling activities were curtailed for four weeks when wet weather prevented the use of the unballasted landings and roads.

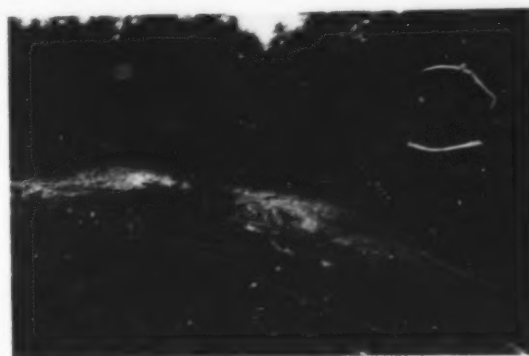


Figure 6. Landing conditions in December.



Figure 7. Skidding routes determined by skidder operator.

Volume Produced

The volume produced from the 19-ha study area is listed by species and grade in Table 2. Approximately 11 000 m³, or 577 m³/ha, was harvested from the study area, including some right-of-way timber adjacent to Block A. The species composition was primarily Douglas-fir and balsam, with minor amounts of alder, pine, cedar, and maple. Approximately 14% of the total volume was comprised of Douglas-fir veterans scattered throughout the blocks. Skidding

Table 2. Species and Grade Distribution: Actual Production

Species	Distribution		Grade ^a						Total (%)
	Volume (m ³)	%	C (%)	H (%)	I (%)	J (%)	X (%)	Y (%)	
Fir	9 244	84	2	22	9	45	19	3	100
Cedar	25	<1	-	-	33	51	16	0	100
Hemlock	44	<1	-	-	50	7	39	4	100
Balsam	1 416	13	-	<1	31	48	19	2	100
Pine	238	2	-	1	2	63	33	1	100
Total	10 967	100							

^a Log grades: G - Peeler, H - Sawlog, I - Sawlog, J - Small sawlog, X - Low-grade sawlog, Y - Pulp.

specifications included all full-length stems and pieces over 3-m long with a minimum 12.5-cm top diameter. Loading specifications included only pieces over 4-m long, with a minimum 15-cm top diameter, that were at least 50% sound wood.

Shift-Level Analysis

Table 3 presents the shift-level time distribution for all shifts with production, for each of the three skidding machines. The 1987 Caterpillar 518 skidder was the primary skidding machine, and it worked in the study area for 32 shifts. The 1981 Caterpillar 518 skidder and the Caterpillar D4H skidder worked 19 and 12 shifts respectively; the remaining shifts were idle time or were spent working in adjacent blocks not included in the study. All operations were conducted on an 8-h shift basis, although loading was frequently active for 12 h/day. Production was allocated between the machines, based on the operators' daily piece counts.

Productive machine hours refers to all time attributable to the skidding function, including minor delays. Non-mechanical delay time refers to those time periods in excess of 10 min when the skidder was available for work, but did not work because of company-controllable organizational delays or non-controllable operational delays. Appendix III lists in detail all the activities of the three skidders during the study period.

All machines experienced very little operational delay time, however, both rubber-tired skidders encountered frequent organizational delay time while waiting for access to the landing. This was caused by inadequate landing size, poor surface condition, and the need to wait for the loader. The Caterpillar D4H seldom skidded during the periods when the landing delays occurred, so it was not affected to the same degree as the others.

Mechanical delay time is that time when the unit is not available for work within its normal shift. The mechanical availability of each skidder was approximately 95%. Mechanical delays for the 1987

Caterpillar 518 were caused mainly by mainline or choker repairs and hydraulic line problems on the winch and blade.

A total of 8056 stems were skidded during the study period, for a total volume of 10 967 m³ and an average volume of 1.36 m³/stem. The average production/PMH was 28.2 m³ for the 1987 Caterpillar 518 skidder, 24.6 m³ for the 1981 Caterpillar 518 skidder, and 15.6 m³ for the Caterpillar D4H skidder. The corresponding average production/8-h shift for the three skidders was 192 m³, 161 m³, and 117 m³. Productivity for the Caterpillar D4H was low for several reasons: its travel speed was slower than that of the rubber-tired skidders, it worked on the steeper slopes, it was used for skidding the oversized logs, and it was used on an inconsistent basis.

Based on estimated machine costs (excluding interest) of \$58.95/h for the Caterpillar 518 skidders and \$58.74/h for the Caterpillar D4H skidder (Appendix IV), the average skidding cost was \$2.46/m³ for the 1987 Caterpillar 518, \$2.92/m³ for the 1981 Caterpillar 518, and \$4.02 for the Caterpillar D4H. However, in the authors' opinions, had the two types of skidders both operated under equal conditions, the difference in productivity would have been only slightly less because of the D4H skidder's lower travel speed. Using the D4H allowed the contractor more operational flexibility than using only rubber-tired skidders.

Non-mechanical delays were caused mainly by the poor landing conditions (Figure 8). For the 1987 Caterpillar 518 skidder, there were 40 delays over 10-min duration, and 35 of these were caused when the skidder was required to clear mud from the landing, pull trucks through the landing, or wait for the loader. The skidder also spent approximately six hours constructing roads and landings, or making repairs. In total, these organizational delays accounted for 19.6 h, or 82% of the 24 h of non-mechanical delay time. For the 1981 Caterpillar 518, 85% of the non-mechanical delay time of 19.6 h (1.03 h/shift) was caused by activities in the landing or by the

Table 3. Shift-Level Time Distribution: Shifts with Production

Phase	1987 Caterpillar 518		1981 Caterpillar 518		Caterpillar D4H	
	h	h/shift	h	h/shift	h	h/shift
Productive machine hours (PMH)						
Skidding time	225.9		125.3		97.1	
Other	0.2		0		0	
Subtotal	226.1	7.1	125.3	6.6	97.1	8.1
Non-mechanical delay time						
Operational	0.7		1.7		0.5	
Organizational	23.8		17.9		1.0	
Subtotal	24.5	0.8	19.6	1.0	1.5	0.1
Mechanically ready hours (MRH)	250.6	7.9	144.9	7.6	98.6	8.2
Mechanical delay time						
Mechanical wait	0.0		0.0		0.0	
Repair	11.9		4.6		3.3	
Service	3.4		3.1		1.6	
Subtotal	15.3	0.5	7.7	0.4	4.9	0.4
Scheduled machine hours (SMH)	265.9	8.3	152.6	8.0	103.5	8.6
Utilization (U = PMH/SMH) (%)	85.0		82.1		93.8	
Availability (A = MRH/SMH) (%)	94.2		95.0		95.3	
Productive shifts	32		19		12	
Pieces skidded	4 681		2 262		1 113	
Volume skidded (m ³)	6 372		3 080		1 515	
Production/PMH (m ³ /PMH)	28.2		24.6		15.6	
Pieces/PMH	20.7		18.1		11.5	
Production/8-h shift (m ³)	192		161		117	
Machine costs (\$)	58.95		58.95		58.74	
Average skidding cost/m ³ (\$)	2.46		2.93		4.02	



Figure 8. Muddy conditions on Landing 4 in Block B.

loader. Non-mechanical delay time for the Caterpillar D4H skidder was negligible.

Table 4 lists repair and service times for the three skidders. The mechanical downtime ratio (MDR) is the number of repair or service hours required per

100 productive machine hours. The MDR was 9.4 for the 1987 Caterpillar 518, 6.2 for the 1981 Caterpillar 518, and 5.1 for the Caterpillar D4H.

Repairs to the winch and blade hydraulic lines accounted for 51% of the repairs on the 1987 Caterpillar 518 skidder; six hours of these repairs were made outside scheduled working time. Repairs to the mainline and chokers were the most frequent, but repairs were made quickly.

Detailed-Timing Analysis

The 1987 Caterpillar 518 skidder was the prime skidding machine, and the other two skidders were used only intermittently. Therefore, detailed timing was restricted to the one machine. Detailed-timing data were collected for one day in Block A and nine days in Block B, and represented a variety of slopes, soil types, soil moisture contents, weather, stem sizes, species, and skidding distances. During three days of detailed timing, each stem was scaled to B.C. Ministry of Forests standards, by a licensed scaler, as it was bucked in the landing, and the volumes for

Table 4. Mechanical Downtime Ratio for the Skidders

Cause of downtime	1987 Caterpillar 518		1981 Caterpillar 518		Caterpillar D4H	
	h	MDR ^a	h	MDR ^a	h	MDR ^a
Repairs						
Carrier	1.3	0.57	1.4	1.12	0.0	0.00
Power system	0.0	0.00	1.3	1.04	0.2	0.21
Winch	13.3	5.88	1.3	1.04	3.1	3.19
Blade	3.3	1.46	0.6	0.48	0.0	0.00
Subtotal	17.9	7.91	4.6	3.68	3.3	3.40
Service	3.4	1.50	3.1	2.47	1.6	1.65
Total repair and service	21.3	9.41	7.7	6.15	4.9	5.05
Productive machine hours	226.1		125.3		97.1	

^a MDR (mechanical downtime ratio) = Number of repair and service hours/100 PMH.

each turn were tallied. A total of 407 stems were scaled, and the average stem size was 1.06 m³/stem.

A production summary for the ten-day detailed-timing period is presented in Table 5. The maximum skidding distance encountered during the detailed-timing period was 440 m; this was also the maximum skidding distance for the entire study. The 1987 Caterpillar 518 averaged 27 stems/PMH, or 29 m³/PMH, during the detailed-timing period.

The summary of productive time (Table 6) includes minor delays. Of the 49.17 h of productive time, 95% was net skidding time and 5% was minor delay time. Poor landing conditions, waiting for the loader, and aiding the log trucks accounted for 58% of the minor delays. A further 12% of the minor delays involved discussions which often pertained to the poor landing conditions. Minor mechanical delays were the result of a broken mainline or chokers. Nine percent of the minor delays were caused when the skidder became stuck on high stumps.

Delays greater than 10 min that occurred during the detailed-timing period were excluded from the detailed-timing analysis. However, a separate examination of these delays confirmed the trend seen in the shift-level analysis where approximately 40% of the long-duration organizational delays were caused by poor conditions on the road and landing.

Table 6 shows the average skidding cycle element times (see Appendix V for element definitions). The net skidding time was 9.69 min/turn, and the productive time was 10.17 min/turn. The longest single element was hookup time, although travel-empty time and travel-loaded time combined accounted for 33% of the net skidding time.

Table 5. Detailed Timing: Production Summary

Element	Production
Maximum skidding distance	440 m
Average skidding distance	161 m
Productive time ^a	49.17 h
Turns skidded	290
Stems skidded	1 339
Number stems/turn	4.62
Average volume/stem	1.06 m ³
Average volume/turn	4.9 m ³
Total volume skidded	1 421 m ³
Average total time/turn	10.2 min
Turns/PMH	5.9
Stems/PMH	27.2
Volume/PMH	28.9 m ³

^a Includes minor delays.

Regression Analysis. Regression analysis, using the least-squares method, was used to test the correlation between the element times and skidding distance. The resulting r^2 values are shown in Table 7.

The highest correlation was between travel-loaded time and skidding distance, with a much lower correlation between travel-empty time and skidding distance. FERIC observed that the skidder usually travelled directly from the hookup site to the landing, but often took a longer route from the landing to the hookup site. Skidding distance was measured along the travel-loaded path, not the travel-empty path, and this likely accounted for the lower-than-expected r^2 for the travel-empty element. Therefore, to include travel-empty time as a function of skidding distance, the analysis of travel times is based on the sum of travel-empty time plus travel-loaded time.

Table 6. Summary of Productive Time from Detailed Timing

Phase	Min/cycle	Percent	
		Phase	Total
Net skidding time			
Travel empty	1.25	13	
Position	1.75	18	
Hookup	2.42	25	
Winch	0.62	6	
Travel loaded	1.89	20	
Unhook	0.77	8	
Deck	0.99	<u>10</u>	
Subtotal	9.69	100	95
Minor delays			
Landing condition or loader		13	
Discussions		12	
Aid logging trucks		5	
Aid faller/bucker		3	
Stuck on stumps		9	
Mechanical		8	
Miscellaneous		<u>10</u>	
Subtotal	<u>0.48</u>	100	<u>5</u>
Productive time	10.17		100
Number of turns			
		290	

Table 7. Correlation Between Element Time and Skidding Distance

Elements	Correlation coefficient (r^2)
Travel empty	0.18
Position	0.02
Hookup	0.00
Winch	0.01
Travel loaded	0.45
Unhook	0.00
Deck	0.00
Cycle	0.18
Travel-empty-plus-travel-loaded	0.43

Regression analysis was also done to examine the effect of the number of stems on the positioning, hookup, and unhook times. No significant correlations were found between these elements. FERIC also observed that the operator often repositioned the stems with the skidder to help reduce the hookup time; once the operator dismounted from the skidder, the extra time required to hookup more stems increased slightly (Figure 9). Furthermore, the time required to position the logs for one turn could affect hookup time for a later turn from the same pile, e.g. less hookup time would be required if some logs remained after the first turn.

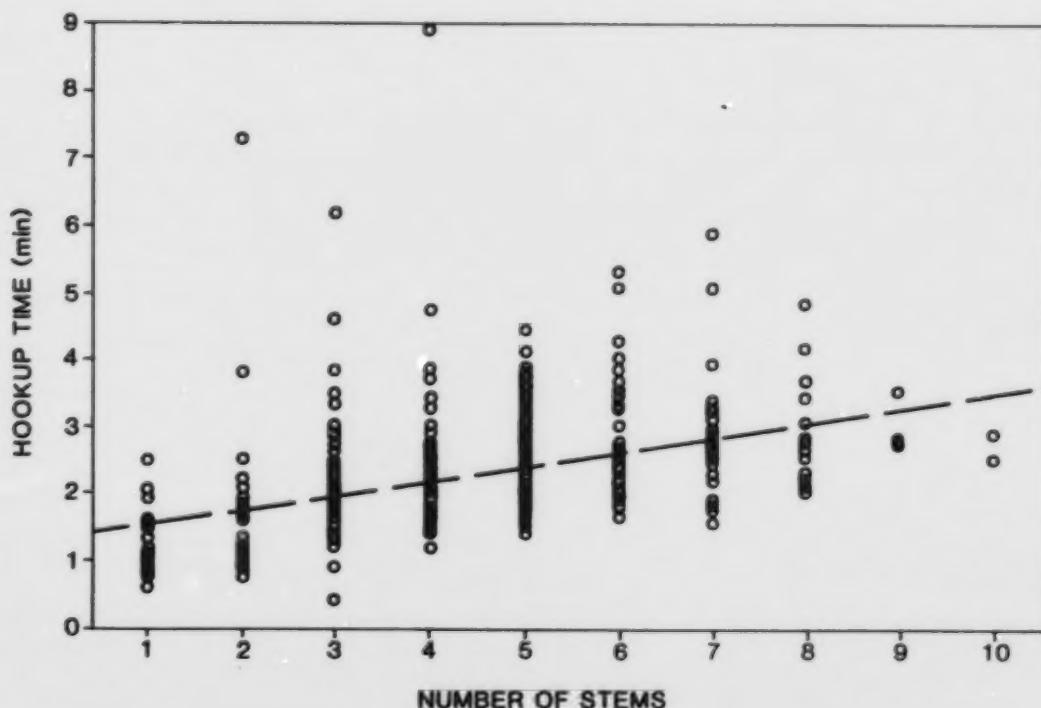


Figure 9. Hookup time versus number of stems/turn.

The relationship between travel-loaded speed and the number of stems skidded at one time was also examined. No correlation was found.

The regression analysis confirmed the on-site observations that the element times and total skidding times were poorly correlated to skidding distance or the number of stems, but were more often the result of unmeasured factors such as the number of stumps encountered on the skid trail, brush at the hookup site, poor stem alignment, and muddy and rutted skid routes. FERIC also observed that skidding heavy, old-growth, Douglas-fir logs increased the time for all the cycle elements.

Skidding Times and Costs. From the preceding analysis it was determined that the best model for cycle times would incorporate the average times for all the cycle elements except for travel-empty-plus-travel-loaded time. The travel time would be based on a linear relationship with skidding distance:

$$(TE + TL) = 0.46 + 1.66 d$$

Where: (TE + TL) = Travel-empty-plus-travel-loaded time (min)
d = Skidding distance (m)

Figure 10 shows the actual and predicted travel-empty-plus-travel-loaded times. Table 8 shows the skidding cycle times and costs based on 85% machine utilization. Total cycle time ranged from 9.8 to 16.6 min/turn for skidding distances between 50 m and 400 m. The corresponding costs ranged from \$9.62 to \$16.33/turn.

Figure 11 shows the model for total skidding time based on the linear relationship between travel-empty-plus-travel-loaded time and distance and the average times for the other cycle elements. The estimated skidding time ranges from 9.2 to 16.5 min, including the fixed time of 6.6 min, for the range of skidding distances observed during the study.

Table 8. Estimated Skidding Cycle Times and Costs

Travel-empty-plus-travel loaded time	$0.46 + 0.0166 d$
Fixed skidding time	6.55
Total skidding time	$7.01 + 0.0166 d$
Minor delays	0.48
Total turn time	$7.49 + 0.0166 d$

Where: Total turn time (min)
d is skidding distance (m)

Utilization = 85%
Caterpillar 518 total cost/h = \$58.95/h

Skidding distance (m)	Turn time (min)	Turn cost (\$)
50	9.79	9.62
100	10.76	10.58
150	11.74	11.54
200	12.72	12.50
250	13.69	13.45
300	14.67	14.41
350	15.65	15.37
400	16.62	16.33

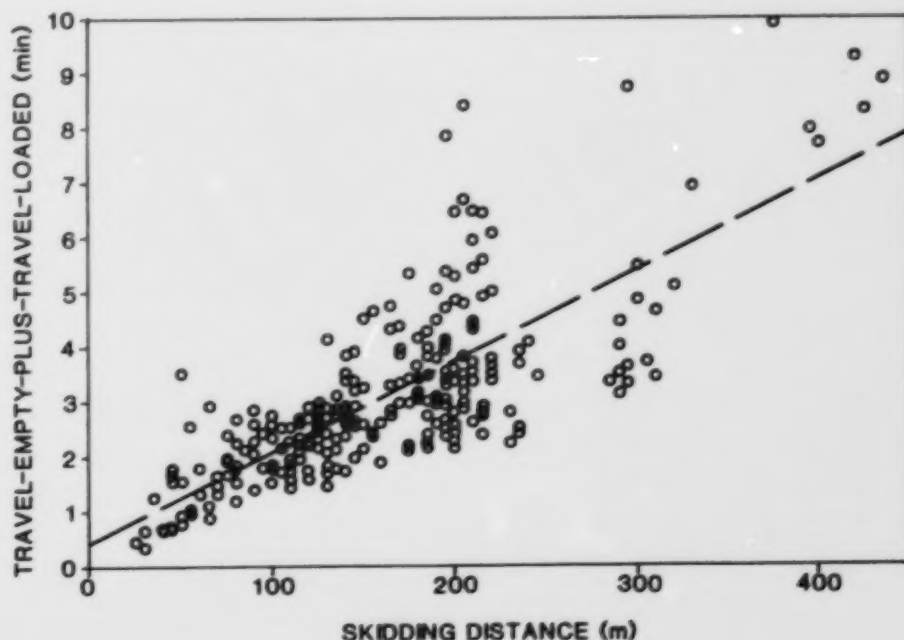


Figure 10. Actual and predicted travel-empty-plus-travel-loaded time versus distance.

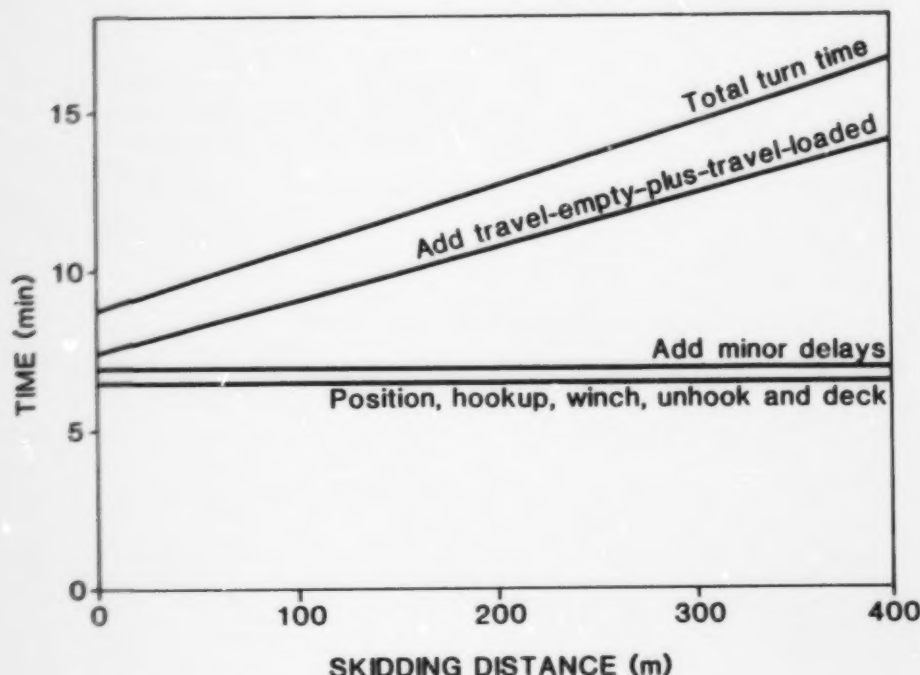


Figure 11. Estimated cycle times for Caterpillar 518 skidder.

Marginal turn size analysis. Marginal analysis is a technique which can be applied to any aspect of the logging system to determine the profitability of that particular phase. For example, for the skidding phase, marginal analysis can be used to determine the minimum turn volume with sufficient volume to balance the variable skidding costs plus the post-skidding costs (PSC) such as bucking, loading, and trucking.

Marginal turn size analysis will determine whether it is profitable to skid a given log. Sunk costs such as equipment ownership, road development, and falling have no bearing on the marginal turn size analysis, however, it is only through profitable skidding that the sunk costs are recovered.

While harvesting economics is an important consideration in determining utilization standards, it cannot be the sole consideration. Fibre supply, silvicultural costs, nutrient status, public opinions, and other factors must also be considered. However, it is only through a clear understanding of both economic and environmental considerations that rational decisions regarding fibre utilization can be made. The purpose of this analysis is to address only the economic considerations relative to skidding operations on a given site.

For this analysis, log-market values were based on the Vancouver Log Market six-month average as of November 15, 1988 (Appendix VI). Appendix VII shows the PSC as estimated by FERIC from the B.C.

Forest Service Coast Appraisal Manual and from typical costs for southern Vancouver Island. Bucking, loading, and hauling costs were calculated per load, then converted to costs per cubic metre. The trucking costs were prorated between the dryland log sorts at Ladysmith and Sooke, based on the actual experience during the study. The stumpage rate was estimated at \$10.44/m³, which was the Coastal average for January 1, 1988.¹ Sales expenses were estimated at 2.5 % of market value. The estimated PSC for the study area were \$23.90/m³ plus sales expense.

After a turn of multiple stems had been skidded to the landing and bucked, it was difficult to identify which logs in the turn had been marginal logs.

Therefore, the marginal turn volume, determined for turns containing only one species and grade, was calculated using the following equation:

$$\text{Marginal turn volume} = \frac{\text{VTC}}{\text{LV-PSC}}$$

Where: VTC = Variable turn cost (\$)
 LV = Log value (\$/m³)
 PSC = Post-skidding cost (\$/m³)

Table 9 presents the turn time, variable turn cost, and marginal turn volume for various skidding distances

¹Source: B.C. Ministry of Forests, Valuation Branch; 1988; personal communication.

Table 9. Marginal Turn and/or Log Volume by Skidding Distance

Where: Total turn time (min) d is skidding distance (m)			
Utilization = 85%			
Caterpillar 518 variable cost/h = \$48.13/h			
Vancouver log market (LV) =	J-grade	X-grade	Total post-skidding phase costs (PSC): \$23.90/m ³ + 0.025 x LV
Douglas-fir	\$41.53	\$21.12	Marginal turn volume = $\frac{VTC}{(LV - PSC)}$
Balsam	\$46.04	\$29.55	

Skidding distance (m)	Turn time (min)	Variable turn cost (\$)	Marginal turn volume			
			Douglas-fir J-grade (m ³)	Douglas-fir X-grade (m ³) ^a	Balsam J-grade (m ³)	Balsam X-grade (m ³)
50	9.79	7.85	0.47	-	0.37	1.60
100	10.76	8.64	0.52	-	0.41	1.76
150	11.74	9.42	0.57	-	0.45	1.92
200	12.72	10.20	0.61	-	0.49	2.08
250	13.69	10.98	0.66	-	0.52	2.24
300	14.67	11.77	0.71	-	0.56	2.40
350	15.65	12.55	0.76	-	0.60	2.56
400	16.62	13.33	0.80	-	0.64	2.72

^a All Douglas-fir X-grade logs were submarginal regardless of skidding distance.

for Douglas-fir and balsam J- and X-grade logs. These species and grades comprised 63% of the volume in the study block, and are representative of many Coastal second-growth stands on southern Vancouver Island. The variable cost for the 1987 Caterpillar 518 skidder used in the analysis was \$48.13/h. Figure 12 shows some typical logs examined in the marginal log analysis.

The marginal turn volume for Douglas-fir J-grade logs ranged from 0.47 m³ to 0.80 m³ for skidding distances of 50 m to 400 m. The market value for balsam J-grade logs was higher, and the marginal turn volume ranged from 0.37 to 0.64 m³ for the same skidding distances. Note that the marginal turn volume at the longest distance is smaller than the average stem size recorded during the study (Table 1). Therefore, a turn consisting of only one average-sized Douglas-fir J-grade log would be profitable to skid regardless of skidding distance. Similarly, the balsam J-grade logs would be profitable to skid singly at all distances.

The PSC for Douglas-fir X-grade logs was greater than their market value, therefore, Douglas-fir X-grade logs were unprofitable for all skidding distances. The marginal volume for balsam X-grade logs ranged from 1.60 to 2.72 m³ for the same skidding distances. All Y-grade logs had PSC greater than their market value and were unprofitable to skid.

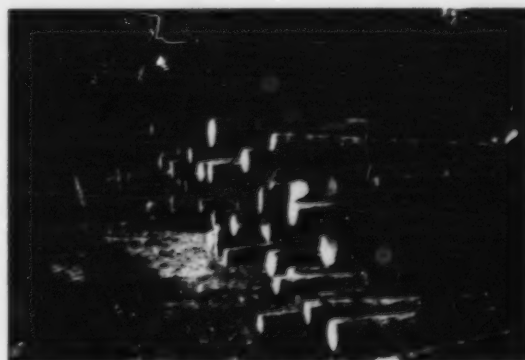


Figure 12. J-grade logs decked on landing and waiting for loading.

During the study, 22% of the volume was X- and Y-grade logs.

It was shown earlier that the number of stems/turn and turn volume had no significant effect on skidding productivity, however, larger turn volume had a great effect on skidding profitability. Table 10 shows profit by turn volume for a range of volumes of Douglas-fir J-grade stems. Net profits per turn ranged from \$104.10 for a 10-m³ turn to a loss of \$3.75 for a 0.5-m³ turn. In comparison to the marginal turn volume, the average turn volume over the three days of scaling was 6.2 m³, ranging from 1.3 m³ to 13.0 m³.

Table 10. Estimated Profitability of Skidding Douglas-Fir J-Grade Logs 160 m^a

Turn volume (m ³)	Turn profit (\$)
0.5	-3.75
1.5	7.61
2.0	13.28
4.0	35.99
6.0	58.69
8.0	81.39
10.0	104.10

^aLog value = \$41.53/m³.

Marginal turn volume = 0.83 m³

Post-skidding costs = \$29.14/m³

The average stem volume during the three days was 1.06 m³, and the number of stems/turn ranged from 1 to 10, with an average of 7 stems/turn.

Logging Residue

Following completion of all skidding activity within the study blocks, FERIC conducted residue sampling of the areas to determine the volume of timber left on the ground. Sampling by the line intersect method indicated a residue volume of 28.3 m³/ha in Block A and 11.2 m³/ha in Block B for a weighted average of 17.3 m³ for the combined area. The average volume of the pieces was 0.2 m³, with an average top diameter of 11 cm and an average length of 4.7 m.

CONCLUSIONS

Two Caterpillar 518 skidders and one Caterpillar D4H skidder were monitored as they skidded Coastal second-growth timber. The species distribution in the study area was primarily Douglas-fir and balsam, and the average stem volume was 1.36 m³. The cruise volume averaged 577 m³/ha, and an average of 17.3 m³/ha of residue remained after logging.

Most skid trails had favourable grades, but some short adverse slopes and wet or non-existent skid trails reduced productivity. Poor landing conditions and loader-related delays caused most operational delays.

Productivity averaged 28.2 m³/PMH for the 1987 Caterpillar 518 skidder, 24.6 m³/PMH for the 1981 Caterpillar 518 skidder, and 15.6 m³/PMH for the Caterpillar D4H. Productivity per 8-h shift was 192, 161, and 117 m³ respectively, and the skidding costs averaged \$2.46, \$2.93, and \$4.02/m³. Machine utilization averaged 85%, 82%, and 94% for the three skidders, and the mechanical availability averaged about 95%.

Regression analysis showed that only travel-loaded time and travel-empty-plus-travel-loaded time corre-

lated to the skidding distance. Skidding distance accounted for 43% of the variation in travel-empty-plus-travel-loaded time. There was a weak correlation between hookup time and the number of stems in the turn, but FERIC observed that hookup time was influenced more by the time spent positioning the stems, than by the number of stems in the turn. No correlation was found between travel-loaded speed and the number of stems in the turn.

Based on a linear equation model for travel-empty-plus-travel-loaded time versus skidding distance, and average times for positioning, hookup, unhook, and delays, it was determined that the total turn time ranged from 9.8 to 16.6 min for distances between 50 and 400 m. The skidding cost ranged from \$9.62 to \$16.33/turn.

Marginal log analysis showed that Douglas-fir X-grade and all species of Y-grade logs were unprofitable to skid. However, the average stem size of the Douglas-fir J-grade logs was 1.06 m³, and the marginal turn volume at the longest skidding distance was 0.80 m³. Thus, a turn containing only one average-sized Douglas-fir J-grade stem was profitable to skid. The same trend was true for all species and grades more valuable than X-grade Douglas-fir.

The number of stems per turn, or turn volume, had no significant effect on skidding cost, but it did have a significant impact on profitability. For turns of Douglas-fir J-grade logs skidded from 160 m, the net skidding profit ranged from a loss of \$3.75 for a 0.5-m³ turn to a profit of \$104.10 for a 10-m³ turn.

This study demonstrated that ground skidding is a viable alternative to cable yarding on some Coastal sites, but that weather conditions in the fall can hamper productivity. Operations must take advantage of drier periods of weather in order to achieve maximum productivity. It also demonstrated that high post-skidding costs make it unprofitable to skid low-grade logs when they are priced according to the Vancouver log-market prices.

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- Caterpillar 1988. Caterpillar performance handbook. (19th edition). Caterpillar, Inc. Peoria, Illinois. 768 pp.
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APPENDIX I

Specifications for Caterpillar 518 Cable Skidder

Engine: Caterpillar 3304 turbocharged four-cylinder diesel, 7-L displacement, 97 kW flywheel power @ 2200 rpm.

Transmission: Planetary power shift with single-stage torque converter.

Speeds with standard tires

	1st	2nd	3rd
Forward, km/h	6.1	12.2	23.3
Reverse, km/h	7.4	14.8	28.3

Axles: Front and rear fixed to frame.
Front and rear NoSpin differentials.

Final drives: Planetary reduction all-wheel drive.

Steering: Articulated frame. Full hydraulic control. 45° range.
Turning radius (outside front):
Narrow-tread tires 5.5 m
Wide-tread tires 5.6 m

Brakes: Driveline and front-wheel discs.

Arch: Integral arch with fixed roller position.

Winch: Caterpillar 518 hydraulically controlled.
Line pull (max. at stall) 15 300 kg
Line speed (@ rated engine rpm) 70 m/min @ 5 443 kg
Max. line speed (bare drum) 138 m/min
Drum capacity 96 m of 16-mm wire rope
Drum diameter 190 mm
Drum width 241 mm

Weight: 10 070 kg

APPENDIX II

Specifications for Caterpillar D4H Custom Skidder

Engine: Caterpillar 3204 turbocharged four-cylinder diesel, 5.2-L displacement, 67 kW flywheel power @ 2200 rpm.

Transmission: Caterpillar planetary power shift with single-stage torque converter.

Speeds with power shift transmission (approximate)

	1st	2nd	3rd
Forward, km/h	3.5	6.2	10.2
Reverse, km/h	4.3	7.5	12.2

Final drives: Single reduction planetary.
Modular, elevated design with segmented sprocket.

Track roller frame: 7 rollers on each side.

Steering: Hydraulically actuated, multiple-disc, oil-cooled steering brakes and clutches.

Track: Sealed and lubricated, standard with two-piece master link and hydraulic track adjusters.

Gauge	2000 mm
Length of track on ground	2 636 mm
Contact area, standard shoe	2.42 m ²
Width of standard shoe	460 mm
Grouser height from ground	47 mm
Ground pressure with standard shoe	0.51 kg/cm ²

Winch: Carco 54, three-valve hydraulics.

Line pull (max. at stall)	22 680 kg
Max. line speed (bare drum)	107 m/min
Drum capacity	96 m of 19-mm wire rope
Drum diameter	254 mm
Drum width	254 mm

Weight: 12 380 kg

APPENDIX III

Shift-Level Time Distribution

	1987 Caterpillar 518 (h)	1981 Caterpillar 518 (h)	Caterpillar D4H (h)
Productive time			
Skidding	225.9	125.3	97.1
Move in block	0.2	-	-
Operational delays			
Unexplained delay	-	0.6	0.5
Crew discussion	-	1.1	-
FERIC discussion	0.7	-	-
Organizational delays			
Delayed by loader	10.6	15.7	0.6
Delayed by hauling	3.0	0.5	-
Delayed by landing activities	2.2	-	-
Delayed by road construction	5.4	0.4	-
Delayed by skidder	-	-	0.4
Miscellaneous delay	2.1	-	-
Operator working on other activity	-	1.3	-
Mechanical delay			
Carrier repair			
Fuel line	-	-	0.2
Tires	1.3	0.9	-
Brakes	-	0.5	-
Lube/filters	-	1.3	-
Winch/lines			
Hydraulic lines	4.9	-	-
Hydraulic pump	0.8	-	-
Cable/chokers	1.6	1.3	2.4
Unexplained	-	-	0.7
Out of shift	6.0	-	-
Blade			
Hydraulic lines	3.3	-	-
Miscellaneous	-	0.6	-
Service delay			
Warm up	1	1.5	0.4
Daily service	2.1	1.4	1.2
Fuelling	-	0.2	-
Power-system service	0.3	-	-

APPENDIX IV

Machine Costs

	Caterpillar 518 cable skidder	Caterpillar D4H skidder
Ownership costs		
Purchase price (P) \$	127 500	148 000
Expected life (y) yr	5	5
Hours/year (h) h	1 800	2 000
Interest rate (I) %	12	12
Insurance rate (Ins) %	2.2	2.2
Salvage value (S) = $(0.25 \times P)$ \$	31 875	37 000
Average investment (AVI) = $(P + S)/2$ \$	79 688	92 500
Expected life (H) = $(y \times h)$ h	9 000	10 000
Loss in resale value = $(P - S)/H$ \$/h	10.63	11.10
Interest = $(I \times AVI)/H$ \$/h	1.06	1.11
Insurance = $(Ins \times AVI)/H$ \$/h	0.19	0.20
Total ownership costs \$/h	11.88	12.41
Operating and repair costs		
Fuel consumption (F) L/h	17	15
Fuel cost (f) \$/L	0.40	0.40
Operating supplies/year (O) \$	2500	3 000
Annual repair and maintenance (R) \$	20 000	21 000
Tire or track replacement (T) \$	6 000	8 500
Tire or track life (TL) h	2 500	3 000
Wages (W) \$/h	16.73	16.73
Wage benefit loading (WBL) %	35	35
Fuel cost (FC) = $(F \times f)$ \$/h	6.80	6.00
Lube and oil cost = $(0.15 \times FC)$ \$/h	1.02	-
Lube and oil cost = $(0.20 \times FC)$ \$/h	-	1.20
Operating supply cost = (O/h) \$/h	1.39	1.50
Repair and maintenance cost = (R/h) \$/h	11.11	10.50
Tire or track cost = (T/TL) \$/h	2.40	2.83
Labour cost (LC) = $[W \times (1 + WBL/100)]$ \$/h	22.59	22.59
Overtime = $(LC/8)$ \$/h	2.82	2.82
Total operating costs \$/h	48.13	47.44
Ownership and operating costs		
Excluding interest \$/h	58.95	58.74
8-h shift cost \$/h	471.59	469.96

APPENDIX V

Cycle Elements: Definitions

Time element	Begins	Ends
Travel empty	When skidder starts to travel away from landing.	When skidder stops travel near target turn.
Position	End of travel empty.	When skidder in position and operator leaves machine.
Hookup	End of position.	When turn hooked up and operator re-enters skidder.
Winch	End of hookup.	When skidder starts steady travel towards landing.
Travel loaded	End of winch.	When turn reaches unhooking location on landing.
Unhook	End of travel loaded.	When operator re-enters skidder or skidder moves away from turn.
Deck	End of unhook, or when skidder starts to push logs on the landing.	When skidder moves away from the landing.
Delay	When a productive function is interrupted.	When a productive function recommences.

APPENDIX VI

Average Vancouver Log-Market Values *

Grade	Balsam/ Hemlock (\$/m ³)	Western cedar (\$/m ³)	Douglas fir (\$/m ³)	Pine (\$/m ³)
A	-	-	262	-
B	-	-	149	-
C	80	-	88	-
D	118	127	217	69
E	-	-	-	-
F	-	126	-	-
G	-	-	-	-
H	74	85	74	46
I	66	69	63	22
J	46	56	42	15
K	-	78	-	-
L	-	66	-	-
M	48	-	-	-
X	30	18	21	10
Y	21	3	17	4

* Source: British Columbia Ministry of Forests, Valuation Branch; 1988; personal communication.
Six-month average to November 15, 1988.
Rounded to the nearest dollar.

APPENDIX VII

Estimated Post-Skidding Phase Costs ^a

Bucking	0.70 \$/m ³
Loading	1.75 \$/m ³
Hauling ^b	6.96 \$/m ³
Sort, boom, scale	4.05 \$/m ³
Towing - no allowance	0.00 \$/m ³
Stumpage ^c	10.44 \$/m ³
Net post-skidding phase costs	23.90 \$/m ³
Sales at 2.5% of market value	varies

^a Sources: British Columbia Ministry of Forests, Valuation Branch; 1988; personal communication.
Contractors working in the Southern Vancouver Island area; 1988; personal communication.
B.C. Forest Service Coast Appraisal Manual, Effective from December 1, 1988.

^b Weighted average derived from Coast Appraisal Manual
72% of volume delivered to Ladysmith, B.C.
28% of volume delivered to Sooke, B.C.

^c Six-month Coastal average to November 15, 1988.